Agronomic Requirements of *Euphorbia lagascae:* A Potential New Drought-Tolerant Crop for Semi-Arid Oregon: 2009 Results.

Richard J. Roseberg and Rachel A. Shuck[1]

Background and Rationale

Euphorbia lagascae (Euphorbiaceae- ‘spurge family’) has been recognized as one of the more promising potential new industrial crops for the drier regions in the temperate zone (Roseberg, 1996). In the late 1950s and early 1960s the USDA analyzed many plant species in search of novel chemical compounds. They first recognized that *E. lagascae* was unique among the 58 euphorbs tested (and almost unique among all plants) in that the seed oil contained high

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[1] Associate Professor and Faculty Research Assistant, respectively, Klamath Basin Research & Extension Center, Klamath Falls, OR.

levels of a C_{18} epoxy fatty acid (EFA) known as vernolic acid (12,13 epoxy-cis-9-octadecenoic acid) (Kleiman et al., 1965). *E. lagascae* (hereafter simply called 'euphorbia') is a drought-tolerant native of Spain whose seed contains about 45%-50% oil, of which 60%-65% is vernolic acid (Kleiman et al., 1965; Vogel et al., 1993). Vernolic acid is an EFA of great interest to the paint and coating industry as a drying solvent in alkyd resin paints, a plasticizer or additive in polyvinyl chloride (PVC) resins (Riser et al., 1962; Carlson et al., 1981; Carlson and Chang, 1985; Perdue, 1986), and possibly in pharmaceutical applications (Ferrigni and McLaughlin, 1984). Paints formulated with vernolic acid emit very low levels of volatile organic compounds (VOC) and thus using such paints would greatly reduce the VOC air pollution that now occurs with volatilization of alkyd resins in conventional paints (Brownback and Glaser, 1992; Anon, 1993). The Clean Air Act amendments of 1990 required the reduction of VOC pollutants, and regulations in California have been implemented earlier with greater effect upon the paint industry.

After initially discovering euphorbia's valuable and nearly unique seed oil, the major problem that hindered both breeding and agronomic research needed to develop euphorbia as a crop has been its violent seed shattering habit, combined with its indeterminate flowering and seed habit, making it difficult both to harvest and to measure seed yield. No wild accessions of euphorbia contain a non-shattering trait (Vogel et al., 1993; Pascual-Villalobos et al., 1994). However, in the early-1990s, chemically induced, non-shattering mutants were developed in Spain (Pascual and Correal, 1992; Pascual-Villalobos et al., 1994; Pascual-Villalobos, 1996). These non-shattering seeds were transferred to Oregon State University in the mid-1990s and formed the basis for research conducted at the Southern Oregon Research & Extension Center (SOREC) and the Klamath Basin Research & Extension Center (KBREC) on a sporadic basis starting in 1995.

Euphorbia is highly self-fertile, with pollen transfer occurring before insects can access the floral organs (Vogel et al., 1993). Therefore, outcrossing should be limited. Because of its apparent tolerance to drought and heat, euphorbia appears to prefer a warm growing season and very dry conditions during seed maturation or else it tends to remain green and continue growing. Due to the presence of latex and other potentially irritating compounds in the stems and petioles, it will be important to understand which safety precautions are necessary during harvest and processing. Processing chemistry and product development should continue on a larger scale as more seed becomes available.

Competing Sources of Epoxidized Fatty Acids

Very few plants naturally produce high levels of vernolic acid in their seed oils (Kleiman, 1990) and most of those that do have significant barriers to domestication and agronomic production (Earle, 1970). For example, early on, two other euphorbs (*Cephalocroton cordofanus* and *Cephalocroton peuschelii*) were shown to contain high levels of vernolic acid. However, because they are both perennial shrubs their potential for cultivation was deemed less than that of the annual *E. lagascae*). General consensus is that the three vernolic acid-producing species that appear to have the best chance for domestication are *Euphorbia lagascae* (Kleiman et al., 1965), *Vernonia galamensis* (Carlson et al., 1981; Perdue et al., 1986), and Stokes aster [*Stokesia* *laevis*] (Earle, 1970; Campbell, 1981). It appears that euphorbia is the most drought-tolerant of these three species.

Current sources of EFAs include epoxidized soybean oil, linseed oil (from oilseed flax), and processed petrochemicals (Carlson and Chang, 1985; Perdue et al., 1986; Dierig and Thompson, 1993). However, epoxidation of simple vegetable oils is an expensive process, and petrochemicals are a non-renewable and increasingly imported raw material. The US typically uses over 30,000 tons of EFAs in over 250 million gallons/year of paints and coatings alone (Anon, 1989). In addition, epoxidation of simple oils such as soybean oil results in carbon chains with the epoxide group appearing at various points along the chain. Vernolic acid produced by plants, however, always has the epoxide group on the same carbon atom within the chain, leading to unique and improved properties (Trumbo, 1998).

Crop Status

There is no commercial acreage of euphorbia at present. Research interest and activity has continued both in the US and in Europe on a sporadic basis (Turley et al., 2000). Because of its unique oil properties, it is difficult to predict exact prices and potential grower profits. However, by using epoxidized soybean oil as a surrogate, a value can be roughly calculated for a hypothetical euphorbia crop.

Average monthly prices for US soybean oil ranged from $0.19 to $0.62/lb between 1992 and 2009, and have consistently remained above $0.30/lb since 2007. Based on a soybean oil price of $0.30/lb, and assuming the value would double or triple after conversion to an EFA (Perdue et al., 1986), an already existing EFA such as euphorbia oil would be worth at least $0.60 to $0.90/lb after crushing, or $0.30 to$0.45/lb of seed (assuming 50% seed oil content). This value range has been confirmed in discussions with industry personnel. Obviously there are some costs associated with crushing and purifying the raw euphorbia oil after harvest, but even if the farmer received only half of the oil's market value for the harvested seed, a seed yield of 1000 lb/ac could return $150-$275/ac to the grower at these conservative prices. This calculation does not factor in the potential higher value of euphorbia oil compared to epoxidized soybean oil due to euphorbia oil's greater chemical functionality. Because it seems likely that euphorbia could be grown with reduced input costs compared to other crops, its net return to the farmer would likely be much greater than other crops having similar gross returns.

Comparison with Related Species

When studying the agronomic requirements of potential new crops such as euphorbia, it is helpful to review what is known about related species in terms of their biology, growth and yield potential, current human uses, and response to potential management practices such as chemical weed control.

Although the genus *Euphorbia* includes over 1,600 species, very few are cultivated or used by humans, and those that are used are typically grown as ornamentals or are harvested from wild stands. Examples of the few euphorbs used by humans include: candelilla (*E.*

antisyphilitica), collected in the wild for the hard wax on its surface, and formerly used to treat the disease syphilis; wild ipecac (*E. ipecacuanhae*), used medicinally; and poinsettia (*E. pulcherrima*), an ornamental flower commonly used as a decoration during the Christmas holiday (Bailey, 1976).

Even within the much broader Euphorbiaceae (spurge) family, relatively few species are used by humans. Of the nearly 300 genera in this family, less than 30 contain species that are used by humans, and in almost every case the plant is cultivated only as an ornamental garden plant. The few exceptions that are cultivated for other productive uses include the following genera: *Aleurites* (tung oil tree); *Hevea* (rubber tree); *Manihot* (roots used to make manioc, tapioca, and cassava foods); and *Ricinus* (castor bean oil).

In most cases, however, human use of euphorb species is mainly limited to exploiting wild plant stands, although some intentional cultivation may occur in local areas. Examples of such uses include species within the following genera: *Antidesma* and *Phyllanthus* (edible fruit for preserves); *Croton* and *Joannesia* (oil for varnish or purgative); *Bischofia* and *Putranjiva* (hardwood timber); and *Garcia* and *Sapium* (drying oils and rubber) (Bailey, 1976). These crops are trees and/or are not commonly grown in North America, and thus information regarding their growth requirements and response to agronomic practices is limited, and would not be applicable in this region even if available.

Certain species of the *Euphorbia* genus are serious weeds in the western US, especially in areas of limited moisture. These weeds include: leafy spurge (*E. esula*); prostrate spurge (*E. humistrata*); spotted spurge (*E. maculata*); and nodding spurge (*E. nutans*). Fortunately, our previous studies with *E. lagascae* show that it is susceptible to several common broadleaf herbicides, and does not appear to persist or spread in or near fields where it has been grown.

Goal of Current Studies

Due to euphorbia’s apparent drought tolerance, the potential of growing euphorbia under minimal irrigation on less-productive soils could help reduce water use conflicts in the Klamath Basin and other areas of the arid and semi-arid western US. Thus, given both the potential of euphorbia as a drought-tolerant crop, and the encouraging data from previous studies at SOREC in Medford, OR, we decided to proceed with additional, more detailed agronomic studies over multiple years, beginning in 2008.

In 2009 we repeated some studies done in 2008, but in 2009 they were done only at the KBREC site. The objectives of these studies included examining euphorbia’s response to differences in nitrogen fertilizer, seeding date, and irrigation rate, as well as to compare euphorbia seed types under varying irrigation rates in semi-arid southern Oregon. Excess seed produced from these studies was supplied to USDA-ARS-NCAUR lab in Peoria, IL for chemical processing tests.

Procedures

Studies were conducted at KBREC on a Poe fine sandy loam soil following teff grown in 2008. Three separate experiments were conducted: I) Nitrogen rate response trial; II) Irrigation rate by seeding date trial; III) Seed type by irrigation rate trial. There were three irrigation treatments (‘high’, ‘low’, and ‘none’) and three seeding dates. ‘Good seed’ (bare, cleaned, individual seeds) grown at KBREC in 2008 was used for each trial, except for the seed type by irrigation rate trial (Trial III), which also used ‘partial pods’ and ‘whole pods’. Detailed descriptions of ‘good seed’, ‘partial pods’, and ‘whole pods’ are given in the Trial III section below.

In each trial the euphorbia seed was drilled using a tractor-mounted modified Kincaid (Kincaid Equipment Mfg.) three row plot drill (rows spaced 24-inches apart). Plots were seeded at a rate of 30 seeds/ft^2. During the growing season weeds were controlled by mechanical and manual cultivation. No fertilizer was applied except for in the nitrogen rate response trial.

AC Cultivating Tractor

All plots were harvested with a Hege (Hans-Ulrich Hege) plot combine with a 4.5-ft-wide header. Harvested seed was cleaned using a Clipper seed cleaner and the percentage of ‘good seed’, ‘partial pods’ and ‘whole pods’ were calculated. After the seed was cleaned, ‘good seeds’ were analyzed for oil content by the USDA-ARS-NCAUR lab in Peoria, IL, and oil yield per acre was calculated after correcting for the proportion of ‘good seed’ within the ‘partial pods’ and ‘whole pods’. Precipitation and other weather data were measured by the US Bureau of Reclamation Agricultural Meteorological (AgriMet) automated weather station at KBREC, which also calculated evapotranspiration values (US Bureau of Reclamation, 2009).

All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Analysis of variance was calculated according to the appropriate individual experiment’s design. Treatment significance was based on the F test at the P=0.05 level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student’s *t* test at the 5% level.

I. Nitrogen Rate Response Trial

Materials and Methods

This study was conducted within the ‘low’ irrigation treatment and was arranged in a randomized complete block design with six replications. The trial was seeded on May 8. The nitrogen fertilizer treatments were applied on June 16, and consisted of 0, 40, 80, and 120 pounds of nitrogen per acre, as ammonium sulfate, broadcast on the soil surface. The soil surface was sufficiently wet from the 0.33 inch of rain received the day before plus moisture from the morning dew to dissolve the fertilizer into the soil surface layers. A total of 4.06 inches of irrigation was applied on four dates from May 1 through harvest in addition to 3.95 inches of rainfall that fell during that time (Table 1). The calculated Penman evapotranspiration from May 1 through August 31 was 29.57 inches. The proportion of green, brown and shattered pods was measured on September 14. The trial was harvested on September 16.

Results and Discussion

Overall, seed yields were higher in 2009 than they were in the 2008 nitrogen rate response trial in the ‘low’ irrigation treatment (Roseberg and Shuck, 2008). In 2009, seed yield ranged from 241 to 305 lb/ac, with a mean of 278 lb/ac. Percent whole pods were lower, and oil content and oil yield were higher in 2009. There was no significant difference (P = 0.05) between nitrogen rates for any of the measured parameters (Table 2).

The percent whole pods measurement is an indication of the maturity and/or relative indehiscence of the plants at time of harvest. Percent whole pods ranged from 9.4 to 15.8%, with a mean of 12.3%. The percent whole pods tended to decrease as nitrogen rate decreased, suggesting that plots receiving no nitrogen may have matured somewhat earlier and thus threshed more easily, but these differences were not statistically significant.

The percent green pods, brown pods, and shattered pods is another indication of maturity, as individual seed pods go through their normal progression of green pods, brown pods, and shattered pods as they reach maturity and beyond. It can also be an indication of variation in indehiscence (inherent non-shattering), for example if a particular treatment results in a high percentage of brown pods along with a low percentage of shattered pods. In this trial, differences in the pod data were not significant between nitrogen treatments. However, there was a trend for fewer green pods and more brown pods in the treatment that did not receive any N fertilizer, suggesting that non-fertilized euphorbia may mature earlier, yet with reduced shattering, compared to plants receiving N fertilizer.

Oil content was fairly uniform among the treatments, and did not follow any discernible pattern. Oil yields ranged from 120 to 152 lb/ac, with a mean of 139 lb/ac, and, not surprisingly, followed the same non-significant ranking as seed yield.

The final stand count measurement is an indication of how well the seed germinated and how well the seedlings persisted into healthy plants as of early summer. Stand counts ranged from 5.8 to 14.0 plants per three feet, with a mean of 10.2 plants per three feet, but the stand counts did not appear to respond to the nitrogen rates in any discernible pattern.

II. Irrigation Rate by Seeding Date Trial

Materials and Methods

This study was laid out as a split plot design with irrigation rate as the main plot and seeding date as the subplot. The three seeding dates were April 16, May 8, and May 29. For the April 16 seeding date, the ‘high’ treatment received 7.70 inches of irrigation, the ‘low’ treatment received 4.62 inches of irrigation, and the ‘none’ treatment received 2.66 inches of irrigation (Table 1). Less irrigation was applied to the May 8 and May 29 seeding dates, as shown in Table 1. In each case, the ‘none’ irrigation treatment areas only received one irrigation after each of the three seeding dates, to simulate a spring rainfall soon after seeding. The trial area also received 4.65 inches of rainfall during the growing season. The calculated Kimberly-Penman evapotranspiration was 2.83 inches from April 16 through April 30, 6.68 inches for May, 6.84 inches for June, 8.96 inches for July, 7.09 inches for August, and 5.49 inches for September. The proportion of green, brown and shattered pods was measured on September 14. For the April 16 seeding date, the ‘high’ and ‘low’ irrigation treatments were harvested on September 15, and the ‘none’ irrigation treatment was harvested on September 16. For the May 8 seeding date, all irrigation treatments were harvested on September 16. For the May 29 seeding date, all irrigation treatments were harvested on October 23.

Results and Discussion

Seed yield, percent whole pods, oil content, and oil yield were all higher in 2009 than in the comparable trial in 2008 (Roseberg and Shuck, 2008). The only significant difference between irrigation rates occurred for percent whole pods, although the P value for percent brown pods was only slightly higher than 0.05 (Table 3). In almost every case, the percent whole pods increased as irrigation rate decreased, suggesting that pods produced under moisture stress either mature later or are more difficult to thresh (or both). Although differences between irrigation rates were not significant for percent green pods, brown pods, or shattered pods, the trend was to have less shattering and more brown pods as irrigation decreased, suggesting that pods grown under moisture stress may have matured later, or been less likely to shatter (tending to confirm the percent whole pods data). For euphorbia, where seed shattering is a serious deficiency in wild types, the ability to avoid shattering while the pods mature is a positive characteristic. The ‘high’ irrigation treatment tended to have the highest seed yields, however the differences were not statistically significant. Stand counts also tended to decrease as irrigation rate decreased, but the differences were not significant.

Differences due to seeding date were significant for every parameter measured. Seed yield decreased as seeding date became later, suggesting that a long growing season is necessary to maximize seed yield. Euphorbia oil content typically varies very little regardless of crop management practices, except when significant amount of immature seed is present, which has a lower oil content than mature seed. In this study the latest seeding date had a lower seed oil percent. This was thought to be due to a greater proportion of immature seeds at harvest for the latest seeding date. At harvest, the latest seeding date appeared to be less mature and did not thresh as well as the earlier seeding dates, requiring a period of drying before a second pass through the combine in order to thresh a similar total proportion of seed pods compared to the earlier seeding dates. This observation about maturity at harvest was confirmed by the pod maturity data taken earlier. The proportion of green pods was drastically higher for the latest seeding date (along with a much lower proportion of brown pods and shattered pods).

This conclusion about the effect of seeding date on maturity at harvest in this climate was confirmed by the data showing percent whole pods increased as planting date became later. The combination of lower seed yield and lower oil percent at later seeding dates resulted in a clear decline in oil yield as seeding date was delayed. Final stand counts ranged from 10.7 to 24.3 plants per three feet, with a mean of 17.2 plants per three feet. Stand counts declined as seeding date was delayed for all irrigation treatments.

This study tended to confirm earlier results showing that euphorbia can grow fairly well and produce a reasonable seed and oil yield despite severe drought stress as long as it has reasonably good germination conditions and a sufficiently long and warm growing season.

The only case where the main plot treatment and the subplot treatment were both statistically significant and where the interaction between the two factors was also statistically significant occurred for percent whole pods. Even though this interaction indicates that in at least one case the response due to irrigation did not vary the same way from one seeding date to the next, the highly significant response to each main factor allows interpretation of the clear pattern of response to irrigation and seeding date.

III. Seed Type by Irrigation Rate Trial

Materials and Methods

Euphorbia seed is produced in capsules (also called seed pods) that normally contain three seeds each (Vogel et al., 1993; Verdolini et al., 2004). Each individual seed is contained within a separate, small chamber or section. Thus, the intact capsule (called 'whole pods' or WP) consist of three sections, with each section containing an individual seed. During the harvest process, euphorbia seed will thresh out into one of three forms: 'whole pods' (WP), 'partial pods' or PP (seed still retained in the individual chambers that have separated from one another), and 'good seed' or GS (clean individual seeds that have separated completely from all remnants of the original capsules or pods). During post-harvest seed cleaning, the seed is typically separated (by size) into these three forms. Past analysis has shown that 'partial pods' contain approximately 48.1% 'good seed' by weight, and that 'whole pods 'contain approximately 43.4% 'good seed' by weight.

Good Seed, Partial Pods, and Whole Pods

Once seeds separate into these three forms during harvest and cleaning, it would be difficult to further separate seed from their pods because euphorbia seed is very soft (due to the high oil content) and easily damaged. Thus, it would be useful to know if PP or WP could be seeded directly, and whether they suffer any loss of germination vigor, crop growth, or ultimate yield compared to using GS. In 2009, we seeded all three forms to compare their performance. These were grown under two irrigation rates to evaluate the effect of moisture level on crop growth as a function of seed type.

This study was conducted within the irrigation borders between the 'high' and 'low' irrigation treatments (called the 'high/low' irrigation treatment), and between the 'low' and 'none' irrigation treatments (called the 'low/none' irrigation treatment) described in Trial II above. These irrigation treatments did not receive a known amount of irrigation because they got half their water from one irrigation treatment, and half from another. However, the irrigation rate received by the plots from which data was collected was approximately midway between the two rates (Table 1). Thus, although the irrigation rate is only approximately known, this study allowed us to observe how various seed types responded to relatively more moisture compared to less. It was laid out and analyzed as a split plot design with two irrigation rates as the main plot and three seed types as the subplot, with 16 replications.

The three different seed types (GS, PP, and WP) were seeded on May 8. Plots were seeded at a rate of 30 actual seeds/ft^2, which turned out to be 28.8 lb/ac for GS, 59.9 lb/ac for PP, and 66.3 lb/ac for WP seed types. The proportion of green, brown and shattered pods was measured on September 15. GS plots in the 'high/low' irrigation treatment were harvested on September 16, and on September 18 in the 'low/none' treatment. PP plots in both irrigation treatments were harvested on September 18. WP plots were harvested on September 23 in the 'high/low' treatment. Half of the WP plots in the 'low/none' treatment were harvested on September 18, with the remainder harvested on September 23.

Results and Discussion

Treatment differences among irrigation rates were significant only for oil content and final stand count (Table 4). Oil content was higher at the lower irrigation rate for GS and PP, but not WP. Stand counts were significantly lower at the lower irrigation rate for GS and PP, and also tended to be lower for WP. There was no significant difference among irrigation rates for seed yield, percent whole pods, oil yield, percent green pods, percent brown pods, or percent shatter. Trends for pod data were not consistent among irrigation treatments. The higher irrigation rate tended to increase seed yield only for WP. Despite the significant difference for oil content, oil yield essentially followed the seed yield pattern.

There was no significant difference between seed type for percent whole pods or percent green pods, but differences due to seed type were significant for all other measured parameters. GS tended to have the highest seed yield, and the seed yield of WP was significantly less than the other two seed types. In addition, oil content of GS was significantly higher than for the other two seed types, thus it is not surprising that the oil yield followed the pattern of GS>PP>WP for both irrigation rates.

The stand count pattern in both irrigation treatments was obvious: GS>PP>WP, indicating clear differences in germination despite seeding an equal number of actual seeds for each type. The lower germination of PP and especially WP may be due to one or more reasons: 1) Perhaps pods that thresh less completely do so because they are less mature at harvest, thus the seed within is less likely to be completely mature. 2) Perhaps the pod capsule itself inhibits germination of the seed within, either due to physical effects such as inhibiting water imbibition, or perhaps some chemical in the pod material that germination. The scope of this study does not provide a clear explanation for this germination response.

Although the percent whole pods at harvest was not significantly different due to seed type, the percent of brown pods and shattered pods did show significant differences. WP had significantly higher percent brown pods and significantly lower percent shattered pods of the three seed types. PP values for brown pods and shattered pods were intermediate between WP and GS under the lower irrigation, but were very similar to GS at the higher irrigation rate. This response may be due to one or more reasons: 1) Perhaps WP seed results in plants that produce pods that exhibit the same trait at harvest (less prone to shattering). 2) Perhaps the plants that came from WP were simply slightly less mature at harvest. However, the pattern of green pod percent under lower irrigation (fewer green pods from WP) does not seem to support the idea of WP plants being less mature at harvest, rather it suggests that for some reason the WP seed produces pods at harvest that mature (turn brown) but do not shatter as quickly as pods produced from GS or PP. In addition, at the higher irrigation rate the pattern of green pod percent does not hold, yet the pattern for brown and shattered pods does follow the same pattern, suggesting that the higher percentage of brown pods resulting from WP seed may actually be due to a stronger 'non-shattering' tendency in plants grown from the WP seed, and not simply differences in maturity timing.

The only case where the main plot treatment and the subplot treatment were both statistically significant and where the interaction between the two factors was also statistically significant occurred for final stand count. Even though this interaction indicates that in at least one case the response due to irrigation did not vary the same way from one seed type to another, the highly significant response to each main factor allows interpretation of the clear pattern of response to irrigation and seed type.

Conclusions

Euphorbia is very flexible, and can adapt to many different growing conditions. These experiments confirm that euphorbia is able to survive and produce a harvestable seed yield under completely non-irrigated conditions, but that seed yield is enhanced by some irrigation. Earlier seeding dates tend to result in greater seed yield and earlier maturity. There was no observable benefit from nitrogen fertilization. The 'good seed' tended to out-perform both the 'partial pods' and 'whole pods', therefore it seems beneficial to learn how to process the harvested seed so that a higher percentage is in the form of 'good seed'. Alternatively, we need to better understand the reasons for poorer germination and crop performance resulting from 'partial pods' and 'whole pods' to overcome their deficiencies. As a general rule, oil content was increased under conditions of greater stress, such as less irrigation or later seeding date. However, these differences in oil content were usually not large enough to affect the overall oil yield, which was primarily controlled by the seed yield.

Evaluating earlier seeding dates in combination with irrigation treatments would be helpful in order to better understand the limits of seeding date and irrigation response for euphorbia seed production in southern Oregon. We did not evaluate row spacing or seeding density in the 2009 trials. In the past, euphorbia has sometimes produced greater seed yields at narrow row spacings, and at other times seed yield is increased at wider row spacings; a condition resulting in larger, branchier plants. It would be useful to test euphorbia under a range of seeds/ft^2 and constant row width to see whether seed density within a row or row spacing are the factors that contribute to these differences in growth habit and yield.

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Table 1. 2009 Precipitation & irrigation for euphorbia irrigation rate x seeding date, seed type x irrigation rate, & nitrogen fertilizer trials. Klamath Basin Research & Extension Center, Klamath Falls, OR.

		"High" Block		"Low" Block		"None" Block	
Month	Precipitation (inch)	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications
April	0.70	0.56	1	0.56	1	0.56	1
May	1.74	3.22	3	2.10	2	2.10	2
June	1.84	0.49	1	0.49	1	0.00	0
July	0.17	3.43	3	1.47	1	0.00	0
August	0.20	0.00	0	0.00	0	0.00	0
Total	**4.65**	**7.70**	**8**	**4.62**	**5**	**2.66**	**3**

Table 2. 2009 Growth and yield of euphorbia in response to nitrogen fertilizer. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Nitrogen Rate	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank	Final Stand (per 3 ft)	Rank	Green Pod %	Rank	Brown Pod %	Rank	Shatter %	Rank
High	292	2	15.8	1	50.4	1	147	2	5.8	4	55.0	1	40.6	2	4.4	4
Medium	241	4	11.3	3	50.0	3	120	4	14.0	1	50.2	2	31.7	4	18.1	1
Low	305	1	12.6	2	49.7	4	152	1	9.8	3	50.1	3	38.8	3	11.1	2
None	272	3	9.4	4	50.4	1	138	3	10.2	2	43.5	4	49.9	1	6.5	3
Mean	278		12.3		50.1		139		10.2		49.7		40.2		10.0	
***P* Value**	**0.869**		**0.290**		**0.143**		**0.876**		**0.366**		**0.683**		**0.253**		**0.211**	
LSD (0.05)	NSD		NSD		NSD		NSD		NSD		NSD		NSD		NSD	
CV (%)	50.3		46.1		1.2		51.0		59.2		32.6		37.2		113.0	

Table 3. 2009 Growth and yield of euphorbia in response to irrigation rate & seeding date.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Seeding Date	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank	Final Stand (per 3 ft)	Rank	Green Pod %	Rank	Brown Pod %	Rank	Shatter %	Rank
High	April 16	715	1	5.8	9	50.8	4	363	1	24.3	1	35.7	7	44.6	6	19.7	1
	May 8	551	3	8.5	7	50.8	4	281	3	20.0	3	36.2	6	50.0	3	13.8	3
	May 29	431	6	21.3	2	46.5	9	203	7	12.5	8	84.2	1	8.8	9	7.1	7
Medium	April 16	481	5	6.9	8	51.0	2	246	5	23.0	2	34.6	8	48.0	5	17.5	2
	May 8	422	7	9.5	6	51.0	2	215	6	17.5	5	32.8	9	58.2	1	9.1	6
	May 29	367	9	17.1	3	47.7	8	176	9	13.7	7	81.8	2	14.6	8	3.6	8
None	April 16	653	2	10.4	5	50.3	6	327	2	19.2	4	37.4	5	53.0	2	9.6	5
	May 8	527	4	13.2	4	51.4	1	271	4	14.0	6	41.8	4	48.6	4	9.6	4
	May 29	404	8	23.9	1	48.4	7	195	8	10.7	9	78.8	3	21.3	7	0.0	9
Mean		506		12.9		49.8		253		17.2		51.5		38.5		10.0	
***P* (Irrigation Rate)**		**0.452**		**0.011**		**0.358**		**0.467**		**0.238**		**0.810**		**0.065**		**0.238**	
LSD (0.05)- Irrigation Rate		NSD		3.0		NSD		NSD		NSD		NSD		NSD		NSD	
CV Irrigation Rate (%)		77.9		37.7		3.19		78.4		43.8		31.6		24.7		138.7	
***P* (Seeding Date)**		**<0.001**		**<0.001**		**<0.001**		**<0.001**		**<0.001**		**<0.001**		**<0.001**		**0.002**	
LSD (0.05)- Seeding Date		94		1.3		0.4		47		3.0		6.7		7.6		6.2	
CV Seeding Date (%)		32.0		17.8		1.4		31.9		25.4		22.5		33.9		107.3	
***P* (Irrig. Rate X Seed. Date Interaction)**		**0.645**		**0.016**		**<0.001**		**0.611**		**0.772**		**0.602**		**0.384**		**0.858**	

Table 4. 2009 Euphorbia growth and yield as a function of irrigation rate and seed type.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Seed Type	Seed Yield (lb/ac)	Rank	Percent Whole Pods	Rank	Oil Content (%)	Rank	Oil Yield (lb/ac)	Rank	Final Stand (per 3 ft)	Rank	Green Pod %	Rank	Brown Pod %	Rank	Shatter %	Rank
High/Low	Good	343	1	10.2	6	51.2	2	176	1	34.8	1	31.0	5	55.7	5	13.3	2
	Partial Pod	300	4	11.6	2	50.2	6	151	4	14.7	3	31.0	4	55.8	4	13.2	3
	Whole Pod	201	5	13.1	1	50.8	3	102	5	6.0	5	34.7	2	58.4	2	6.9	5
Low/None	Good	334	2	11.2	3	52.0	1	173	2	21.2	2	34.9	1	51.7	6	13.4	1
	Partial Pod	310	3	10.8	4	50.7	5	158	3	8.8	4	33.1	3	57.2	3	9.7	4
	Whole Pod	128	6	10.4	5	50.8	3	65	6	4.0	6	28.4	6	65.9	1	5.7	6
Mean		269		11.2		51.0		138		14.9		32.2		57.4		10.4	
***P* (Irrigation Rate)**		**0.618**		**0.623**		**0.025**		**0.653**		**0.001**		**0.974**		**0.443**		**0.662**	
LSD (0.05)- Irrigation Rate		NSD		NSD		0.4		NSD		3.6		NSD		NSD		NSD	
CV Irrigation Rate (%)		84		71.0		1.7		85.3		46.7		44.1		17.8		164.2	
***P* (Seed Type)**		**<0.001**		**0.465**		**<0.001**		**<0.001**		**<0.001**		**0.850**		**0.023**		**0.033**	
LSD (0.05)- Seed Ttype		50		NSD		0.3		26		4.1		NSD		6.1		5.4	
CV Seed Type (%)		37.5		29.7		1.3		37.4		47.7		30.6		21.1		104.6	
***P* (Irrig. Rate X Seed Type Interaction)**		**0.239**		**0.107**		**0.082**		**0.212**		**0.022**		**0.095**		**0.176**		**0.797**	